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ON CERTAIN DISEASES

OF

FUNGAL AND ALGAL ORIGIN AFFECTING ECONOMIC PLANTS IN INDIA.

Plates missing

BY

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On certain diseases of Fungal and Algal Origin affecting economic plants in India.

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The following pages contain an account of what I have hitherto been able to ascertain regarding the nature of certain common forms of vegetable blights affecting plants of economic value in India. The materials from which data were obtained are derived from various sources. Most of those illustrative of blights affecting potato crops were supplied by district officers and officials in the Agricultural Department; the specimens of tea and opium blights were forwarded to me by Dr. George King, to whom they had primarily been submitted; those affecting Pinus and Deodar were supplied by Mr. J. S. Gamble of the Forest Department; those on Lucerne and Brinjal by Mr. Mollison, Superintendent of Government Farms, Bombay; whilst those illustrating the blights of the Teak and *Terminalia Catappa* were obtained direct from trees growing in and around Calcutta.

It must at the outset be confessed that the information contained in the present paper regarding most of the blights dealt with is very imperfect. With regard to some of them all that has hitherto been ascertained is that they are of unequivocally fungal origin, and, in hardly any case, has the life-history of the parasite been fully ascertained, owing in part, at all events, to the fact that in very few instances is the disease native to the locality in which it was studied. It is only, then, as a step towards the acquisition of fuller information, and as a means of aiding those who may subsequently have the opportunity of fully working out the subject, that it has been deemed justifiable to publish the data as they stand. It is never satisfactory to put forth incomplete results, but this appears to be one of the occasions on which utility ought to be preferred to inclination and the desire for completeness.

The subject-matter of a paper of this nature might be arranged according to two distinct methods: the various diseases might be grouped according to the nature of the parasites which give rise to them, or of the host-plants in which they occur. The latter method has here been preferred as being of more practical utility to those who have to deal with the matter from an economic rather than a purely scientific point of view, and, on similar grounds, the host-

plants have been arranged, not in the order of botanical taxology, but according to their relative local agricultural importance.

I. Smut-blight of Rice.

This form of blight, which is dependent on the attacks of a Ustilago which fructifies in the ovaries of the grains, apparently only prevails abundantly at comparatively rare intervals, for it produces such very conspicuous effects that it is very unlikely to escape the most casual observation when present in any amount, and yet I have only twice had specimens of it submitted to me for determination,—once several years ago from Chittagong, and again during the course of the present season from Orissa, where it was supposed to be dependent on the action of some insect. In all the specimens, moreover, which I have seen, only one or two grains have been affected in any ear, so that it appears to be not improbable that the rice-plant is not the sole or even the specially favourite host, and that it is only under the influence of certain special climatic conditions which tend to retard growth at a very early stage of development that it is liable to be affected to any appreciable extent.

The grains which are the subject of attack become very conspicuous from the great enlargement which the ovary undergoes as the fungal tissue accumulates within them. They frequently attain dimensions of 0·38″ or more, and as the spores mature and accumulate on the surface, acquire a deep greenish-brown colour, variegated with orange where the immature mycelial tissue is visible, (Plate III, Figs. 7-8). The proper ovarian tissues are ultimately completely destroyed and replaced by a dense web of mycelial filaments which, as they mature, become converted into masses of spores. The latter are spherical, coarsely tuberculate, of a greenish-brown colour, and with diameters of about 8 micromillimetres (Plate III, Fig. 9).

The disease, owing to its apparent rarity and limited extension, would seem to be of comparatively little practical importance, but, were it to make its appearance anywhere to any serious extent, there can be no question that the best way to combat it would be to adopt the measures which have been found by practical experience to be most efficacious in Europe in dealing with blights of similar nature affecting grain-crops. As infection of the host-plants can occur only at a very early stage of their development, the occurrence of the blight in certain individuals of a crop is no source of general infection for their compeers, as it is in the case of a disease of uredinous origin. It is, no doubt, desirable to remove and destroy the affected plants ere the fructification of the parasite has matured, not with any view of preventing further infection of the existent crop, but in order to protect subsequent ones from liability to infection. As the masses of spores mature, they are readily disseminated by the wind in the

form of an impalpable powder which readily adheres to the healthy grains and to the leaves and stems of the same and surrounding plants.

These thus come to be covered with spores which are capable of retaining vitality for periods of years, so long as they are kept dry, and then of wakening up to germinate and serve as a source of renewed infection where their products come into relations with young seedlings of the host-plant. This being the case, it is evident that one most important factor in securing a recurrence of the disease must be the employment of grain which is polluted by adherent spores as seed-corn, unless some special measures are adopted which are calculated to destroy the vitality of the spores without affecting that of the grain. If, therefore, grain derived from a crop affected by the disease must be employed as seed-corn, the practice in Europe is to immerse it for a period of about twelve hours in a solution of sulphate of copper as a reagent which effectually kills the spores without affecting the life of the grain. After having been treated in this fashion, the grain is simply well washed in water and then carefully dried, and practical experience has demonstrated that the procedure does much to limit the prevalence of disease. But as the spores do not adhere merely to the grain, but also to the leaves and stalks of the plants, all straw coming from an infected area must be dangerous, more especially where it enters into the constitution of manure in which the spores will encounter all the conditions for germination and subsequent luxuriant production of the conidia which, when they in their turn germinate, provide the direct means of infection. The straw from any infected crop should, therefore, not be employed in manure, and the residual stubble remaining in the fields ought to be, as far as possible, destroyed. By the adoption of measures of this nature the occurrence and extension of such blights may to a great extent be controlled, but where either crops of like nature are cultivated year after year in the same sites, or where the parasite is not limited to cultivated hosts, but occurs among certain individuals of the natural vegetation of the area, it must be impossible to obviate completely the possibility of renewed infection. Under such circumstances the soil must remain constantly liable to contain varying numbers of spores, and the only remedial measure which can be attempted is to endeavour to promote the rapid growth of the seedling host-plants as much as possible, for we know, thanks to Professor Oscar Brefeld's brilliant series of observations, that, even after the mycelium of the parasite has gained access to the tissues of the host, no harm will follow unless it gains access to the special site in which its further development normally occurs, and that it is incapable of travelling far in search of this. Where, therefore, as in the case of the rice-plant, the site for the ultimate evolution of the parasite lies in the floral organs, it is only at a very early stage in the life of the host that the intrusive mycelium, with its very limited capacity for extension, will be able to reach its aim,—*i.e.*, the embryonic tissue contained in the very apex of the shoot

and representing the rudiments of the flowers; and hence, just in proportion to the rapidity with which the growth of the host primarily occurs, there will be a diminished likelihood of the blight successfully establishing itself. The fact that rice is so much primarily cultivated in seed-beds in place of being sown broadcast in the fields, is thus probably one reason for the very limited extension of the disease, as under such a system of cultivation the conditions providing for very rapid initial growth are, as a rule, generally present.

NOTE.—Since the above was written, Professor Oscar Brefeld of Münster has published a paper in the *Botanisches Centralblatt*,* showing that this disease is not caused by a member of the Ustilagineae, but by an Ascomycete, closely related to *Claviceps purpurea*, which gives rise to ergot in Rye and other Gramineae. As, however, this discovery does not practically affect the measures for prevention which have been recommended, and as true Ustilagineous disease frequently prevails amongst the grain crops in this country to a serious extent the text has been allowed to stand as it originally was.

II.—Blights affecting Potato-crops in India.

a. The common Potato disease of Europe.—This blight, which, as every-one is aware, is dependent on the action of *Phytophthora infestans*, de By., one of the peronosporic group of oomycete fungi, has, of recent years, not unfrequently appeared in epidemic and destructive form, and, in certain parts of the country, such as the Khasi hills, in which the cultivation of the potato has come to a great extent to replace that of indigenous crops, has occasionally seriously affected the food-supply of the population. The introduction of the parasite into the country would certainly appear to have taken place only comparatively recently, and was no doubt effected by means of well-meant but injudicious importation of large quantities of seed-potatoes from Europe, without sufficient precaution that they were not derived from infected stock.

The distinctive characters and the life-history of the parasite, so far as this has as yet been ascertained, are so well known that it is unnecessary to enter into any details regarding them here. Specimens of the disease have reached me from the Khasi hills, from the Darjiling district, and from Kumaon, but none as yet have been obtained from any portion of the plains of India. So far, then, the disease would appear to prevail epidemically only in hill-areas. This fact is no doubt to be accounted for by the differences in the external conditions to which the crops are exposed within the two areas. When cultivated in the hills they are constantly liable to be exposed to those conditions of atmospheric humidity which permit of the development of the aerial fructification of the parasite (Plate I, Fig. 12), of the continued vitality of the sporangia, and of the general diffusion of the zoospores; whilst in the plains, as cold-season

*Der Reis-Brand und der Setaria-Brand, die entwicklungsglieder neuer Mutterkornpilze. Von Oscar Brefeld. Botanisches Centralblatt., Band LXV, 1896.

crops, they are not exposed to such conditions, and consequently, even if the disease is actually imported into a locality, its diffusion must necessarily remain limited. The phenomena are, in fact, precisely parallel to those which we find occurring in Europe, where general epidemic diffusion of the disease is practically regulated by the annual variations in atmospheric humidity.

b. Root-blight caused by the invasion of the tissues by a species of Pythium.—This, like the previous disease, is dependent on the presence of an oomycete fungus, but, unlike it, it occurs in crops cultivated in the plains. Specimens of it have been obtained from Saharanpur, Gurdaspur and Batala, in the Gurdaspur district. The fact of its occurring in the plains, and not, like the Phytophthora disease, being confined to hill-areas, is related to differences in the habit of the two parasites. In the case of Phytophthora the fungus, although occurring in the tubers and roots, finds conditions for extensive diffusion only when it invades the stems and leaves, and having done so encounters an atmosphere of sufficient humidity to permit of the development of aerial fructification. In this case the parasite is limited to the subterranean portions of the host, and here, under the influence of the excessive irrigation to which the crops are ordinarily subjected in this country, finds all the conditions permitting of rapid extension. It is not a pure parasite as Phytophthora is, but is capable of existing saprophytically, and it produces large numbers of oospores, a form of fructification which, if it occurs at all in *Phytophthora infestans* is so rare that it has never yet been met with, and which is capable of lying dormant during prolonged periods of unfavourable conditions and of subsequently assuming activity when no longer exposed to them. There are thus various reasons explaining the extension and persistence of the disease within areas, such as those of the plains of India, in which Phytophthora is incapable of producing any appreciable mischief.

All the specimens of the disease were obtained in February and the early part of March, 1893. In none of them did the foliage or haulms show the faintest trace of the presence of Phytophthora, and the tubers were perfectly healthy, the only peculiarity being that in some specimens of red-skinned ones a narrow zone of bright pink was present in an area corresponding with that in which the fibro-vascular bundles are distributed, an appearance which, as will subsequently be shown, is sometimes mistaken for that characterising the tubers in the so-called "Bangle-blight," but which is not dependent on any morbid textural changes, but merely on the presence of a certain number of cells containing a red colouring matter, like that present in the cortical tissues.

The disease was certainly associated with, and presumably caused by, the presence of a species of Pythium the mycelium and fructification of which were abundantly distributed throughout the cortical and medullary tissues, and, in minor degree, within the deeper portions of the fibro-vascular bundles of the

base of the stem and the larger roots. The mycelium was of characteristically aseptate type save in the immediate neighbourhood of the oospores where a few partitions could occasionally be recognised. The fructification was of two kinds; one presenting the character of asexual sporangia (Plate I, Fig. 15), occurred abundantly within the tissues of the pith, whilst the other, consisting of oospores (Plate I, Figs. 13-14), was present in smaller numbers there, but in excessive abundance within the cells of the cortex. When portions of tissue containing oospores were immersed in water germination presently occurred with the formation of a branched aseptate mycelium, so that there could be no question of the capacity of the fungus for saprophytic existence for some time, at all events, as the tissues of the host were completely dead and consequently incapable of providing for the requirements of a pure parasite.

The oogonia (Plate I, Fig. 14) were colourless and measured about 18μ in diameter. The oospores were considerably smaller than the oogonia, so that they lay quite free within the cavity of the latter. They had a pale ochre tint. No unequivocal evidences of the presence of antheridia could be detected, but this does not necessarily imply a parthenogenetic production of the oospores as all the specimens were more or less completely dried up ere they were examined and contained only fully matured fructification, so that previously existent antheridia might quite possibly have become unrecognisable.

The occurrence of species of Pythium as parasites capable of affecting the potato plant has already been recorded. Sadebeck found a potato-field, near Coblenz, in which his *Pythium Equiseti* or *autumnale* replaced Phytophthora as a cause of blight,* and De Bary has shown that Hesse's *Pythium de Baryanum* attacks potatoes energetically†. As I have not had an opportunity of examining specimens of these species, I am unable definitely to determine whether the present one is identical with either of them, but it would appear probably to be distinct. The oogonia can hardly be described as yellow, as Sadebeck states that those of his species are, and the oospores do not require to pass through a prolonged period of rest as those of *Pythium de Baryanum* do, according to De Bary.

On the assumption that the blight is essentially dependent on the presence of the Pythium, there can be little room to doubt that the proper measures to be adopted in endeavouring to prevent its appearance and limit its extension consist, in the first place, of an avoidance of all excessive irrigation, and, in the second, of the careful removal and destruction by burning of all portions of blighted haulms and roots. Any excessive saturation of the soil must necessarily favour extension of the disease, as it provides the conditions for the saprophytic growth of the mycelium external to the host, and therefore provides the means for primary infection and for spread from plant to plant; and from the abundance of

* Bot. Zeit., 1876, s. 268.

† Bot. Zeit., 1881, s. 520.

oospores which are liable to be present within the tissues of dead and blighted plants, the latter must serve as a means of securing the recurrence of the blight from year to year if they be allowed to remain in the soil of any area within which the cultivation of potatoes is annually conducted. The oospores, being capable of lying dormant for prolonged periods so long as they are kept dry, will readily survive in the soil for an indefinite time and retain their capacity for producing mycelium, primarily of a saprophytic type, but ready to adapt itself to parasitic existence whenever it meets with a suitable host.

c. A leaf-blight termed "Karrah" by the natives of Oudh.—This is a form of blight which differs from the previous one in primarily affecting the leaves and tips of the stems of the host, and has of late years occasioned considerable mischief among crops in the neighbourhood of Lucknow. Specimens of plants affected by it were sent to me by Mr. Ridley, the Superintendent of the Horticultural Garden, Lucknow, in March 1893. They showed no traces of the presence of Phytophthora, but the tissue of the leaves was everywhere permeated by mycelium, whilst the surface was covered by a crop of emergent fructifying filaments of two distinct forms. One, and by far the most abundant of these, consisted of erect, unbranched filaments capped by clusters of large, colourless, uniseptate, obovate conidial bodies which germinated freely in water (Plate I, Fig. 16). The phenomena attending germination were somewhat peculiar in character, for the conidial cells only germinated directly in a comparatively limited number of instances, whilst in most cases a considerable increase in the size of the cells occurred, and at the same time the contents became clothed with a special cell-wall. The walls of the parent cells then gradually disappeared and the original bilocular conidia came thus to be replaced by pairs of cells, which generally remained associated in couples, but sometimes became completely isolated from one another; and it was not until these preliminary processes had been completed that germination occurred. It appeared in fact as if each of the loculi of the original conidioid bodies became converted into a unisporic sporangium ere germination took place.

The second form of fructification which was present, presented the characters of *Fusisporium Solani*, Mart., occurring in the form of slender branched filaments, which were frequently arranged in the form of dense tufts, bearing slender, septate, curved, fusiform conidia (Plate I, Fig. 16). There can be no question that the mycelium giving origin to this form of fructification cannot reasonably be regarded as the cause of the blight, but had been saprophytically developed within the already dead tissues, and this may have been the case with the other form also. It remains, however, also possible that it may have been the original cause of the disease. It was naturally impossible definitely to settle this question in Calcutta, where potatoes are not cultivated, and where the specimens only arrived after they had been exposed to a journey of several

days' duration, and were consequently hopelessly wilted. The disease was assuredly not caused by Phytophthora, and may have been caused by the first form of fungus described above. This is a question which can only be satisfactorily worked out in localities within which potatoes are cultivated and are subject to the disease, but there the solution of the problem would be extremely easily arrived at by means of a few careful experiments, and it has, therefore, been deemed advisable to publish the results of the present observations, imperfect though they be, in the hope that they may lead to the local study of the subject.

d. "*Bangle-blight.*"—In the spring of the year 1892, Mr. Mollison, Superintendent of Government Farms, Bombay, forwarded some specimens of diseased potato-plants to the Indian Museum for examination, and these were subsequently sent on to me. They had been grown in the neighbourhood of Poona and were affected by a disease ordinarily termed "Bangle-blight" by the native cultivators, as descriptive of the appearance of a characteristic annular brown or blackish line which is present in the substance of the tubers of the affected plant in an area corresponding with that in which the diffused fibro-vascular bundles are situated (Plate I, Figs. 2-3). In the letter which accompanied the specimens, Mr. Mollison stated that the disease did not make its appearance in one spot or patch in a field and radiate thence, but in scattered isolated plants, which wilted suddenly, as though they had been attacked by a cut-worm or grub beneath the surface of the soil. "The haulm rapidly withers and dries up, still retaining its green colour, and in the course of a few days gets brown as a ripe stem would do. A plant which is perfectly fresh one day shows signs of distress on the next one and will be quite wilted and drooping on the third day." He also pointed out that the methods of cultivation universally adopted near Poona appeared to him to be faulty, the crops being grown year after year on the same land and irrigated every eight days to such an extent that the stems were submerged to a depth of an inch or an inch and a half. Judging from the phenomena presented by the disease, Mr. Mollison correctly concluded that it could not be dependent on the presence of Phytophthora, and it was with a view to having this question definitely settled that the specimens were forwarded to Calcutta.

They showed not a trace of the presence of either the fructification or mycelium of Phytophthora. The leaves, although wilted, either retained their green colour or merely showed signs of normal fading, and the haulms throughout the greater part of their course appeared to be perfectly healthy. Just at the base, however, they were somewhat discoloured (Plate I, Fig. 1), and transverse and vertical sections showed the presence of points or streaks of brown within the substance of the vascular bundles (Plate I, Fig. 4), which on microscopic examination were found to be owing to mycelium and minute sclerotia. The fungal

elements appeared to be strictly confined to the wood; the tissues of the bast, cortex, and pith being seemingly entirely free from them. Within the wood, they were present in the interior of the spiral vessels, the wood-cells, and the great pitted ducts. In the latter they were specially abundant, and it was here that the sclerotia giving rise to the streaks and points of brown discoloration, previously alluded to, were present (Plate I, Figs. 5-11). The disease appeared to be limited to the base of the haulm in its subterranean and aërial portions, and a little farther up no traces of it could be detected. The roots appeared to be entirely free of fungal elements, and, what is more remarkable, the tubers also appeared to be entirely exempt even in the sites in which the brown discoloration forming the so-called "bangle" was present.

The characters of the disease are, therefore, typical of those dependent on the presence of a Sclerotinia or other closely allied form of Ascomycete parasite. The distribution of the fungal elements within the host, the presence of sclerotia, and the history of the conditions of cultivation under which the blight originates, are all equally characteristic, and, under these circumstances, there can be no doubt whatever in regard to the preventive measures which ought to be adopted. The source of recurrent infection lies unequivocally in the sclerotia which are situated within the substance of the vascular bundles, and which, after lying dormant for a time in the dead tissues, are the origin of the reproductive elements which invade the new crop of the host-plant, and the germination of these elements and the growth and diffusion of the resultant mycelium must assuredly be favoured by any conditions giving rise to saturation of the soil. It is thus evident that the methods of cultivation described by Mr. Mollison as prevailing near Poona are precisely those which are specially adapted to secure the persistence and extension of the disease. The continuous cultivation of the host-plant year after year within the same areas must tend effectually to secure the constant presence in the soil of sclerotia, and the excessive irrigation must provide special facilities for their farther evolution and for the growth and diffusion of the infective elements ultimately derived from them. But, if this be so, it is equally evident that the proper preventive measures are the careful removal and destruction of all the diseased portions of blighted plants, the abandonment of the system of continuous culture of potatoes within the same areas, and the avoidance of all excessive irrigation.

As the group of blights, of which this is a typical example, would appear to be very prevalent in India, but at the same time to have received very little local attention, it may, for practical purposes, be well to note briefly what are the distinctive features of it. The fungi which are the specific causes of the diseases included in it are, so far as is known, all Ascomycetes distinguished by the fact that the common vegetative mycelium does not give direct origin to a carposporic fructification, but to dense pseudo-parenchymatous masses of felted

filaments termed sclerotia which lie dormant for varying periods and then give direct origin to the carposporic fructification proper to the species. This, in all cases in which the life-history of the species has been fully worked out, is of discomycete type, consisting of shallow, widely open receptacles of saucer-shape, and these in the case of the genus Sclerotinia, to which the majority of the sclerotial blights which have been fully investigated belong, are specially distinguished by the fact that they are borne on the extremities of elongated pedicels, in place of being sessile as the carposporic fructification of the closely allied genus Peziza is. Taking such carposporic bodies as the starting-point of a fresh generation of the fungus, we find them ultimately producing large numbers of asci or sporangia each containing eight spores. The latter are ultimately discharged, and then, under favourable circumstances, germinate and give origin to mycelium. This is capable of growth and often of excessive growth saprophytically, but in most cases only attains its perfect development, as evinced by the production of sclerotia, when it has been enabled to invade the tissues of some host-plant and assume a parasitic existence. The capacity for a purely saprophytic existence is, however, of great utility to the plant in affording facilities for reaching a suitable host, and practically makes up for the frequent absence of any conidial fructification. In the absence of abundant conidial fructification, which is the great means for the aerial dissemination of any blight, the diffusion of any fungal disease would necessarily be very greatly restricted unless a capacity for saprophytic existence were present to permit of very considerable progression of the protoplasm in quest of a suitable host. In any case, in the absence of abundant conidial fructification, the extension of a blight must be more or less slow and limited, but the capacity for saprophytic existence comes in as an important factor in favouring extension. What renders sclerotial blights specially mischievous is the fact that their parasitism is not as a rule highly specialised. They are, ordinarily, capable of attacking various host-plants, and, in addition to this, of existing for prolonged periods saprophytically. Conidial fructification is not, however, invariably absent, although in many cases only rarely produced. Under the influence of certain conditions it is in some cases produced direct from the spores, and in others from the mycelium also, in the form of *Botrytis cinerea* which appears as a mould on the surface of the blighted tissues of the host.

The degree to which parasitism has been evolved appears to differ considerably in different instances. In certain forms commonly occurring in India, the mycelium is capable of invading and of effectually blighting many different hosts without being capable of giving origin to sclerotia within or upon them, whilst in other cases, fully developed sclerotia are produced indifferently in connection with vegetative growth within hosts of most unlike nature. This variation is, of course, of very considerable importance in regulating the extent to which a

blight is liable to recur. The importance of the production of sclerotia lies in the fact that it is this which provides for the persistence of the blight from year to year, in spite of prolonged periods during which external conditions are such as to preclude its activity. So long as external conditions are favourable, very extensive blighting may be effected by means of mere ordinary vegetative growth of mycelium, but, in the absence of sclerotia, there would be no tendency to any regular annual recurrence of the disease. It is evident, then, that any species in which parasitism has been so slightly specialised that sclerotia may be produced in connection with very different hosts, is likely to be more mischievous than one in which, although vegetative growth of mycelium may take place freely in connection with various hosts, the production of sclerotia is limited to cases where the growth occurs within one, or, at utmost, a limited number of hosts.

The importance of the production of sclerotia is strikingly demonstrated by certain phenomena of annual recurrence in Calcutta. Every autumn large unsightly patches of blighted foliage make their appearance on surfaces covered by *Ficus stipulata*. They normally appear first at the level of the surface of the soil, and gradually ascend thence in radiant fashion over areas whose magnitude varies with the nature of the atmospheric conditions which characterise particular seasons. When atmospheric humidity remains persistently excessive over prolonged periods, the extension of the blight is correspondingly great; when it is relatively low and does not last long, the disease remains comparatively limited and in any case, with the onset of the cool and relatively dry weather at the beginning of winter, it is abruptly arrested. If the leaves within a blighted area are examined, it will be found that towards the margins of it and where they are only beginning to be discoloured, their under surfaces are coated with a web of white mycelium, which, in some cases, extends directly from leaf to leaf, and, in others, reaches successive leaves by means of connecting white strings which run along the course of the axis on which they are situated. Where such a string reaches the base of a petiole, it travels out along it and spreads out over the under-surface of the lamina in a layer of divergent white filaments. These adhere closely to the epidermis, and, after they have been in contact with it for a short time, the substance of the lamina becomes first ochreous and ultimately quite dead and brown. In the case, therefore, of leaves in which the disease is still in progress, the under surface shows first areas already discoloured and covered by mycelium; secondly, and immediately adjoining these, others clothed with a layer of mycelium, but still green; and finally, others which are as yet quite healthy. When the leaves have become completely killed and discoloured, sclerotia begin to make their appearance. They, unlike the common vegetative mycelium, are in most cases situated on the upper surfaces of the leaves, and occur specially abundantly there towards the margins of the laminæ (Plate II, Fig. 10). They are developed from tufts of mycelium which break out at points in the

upper surface, and, having done so, ramify in a complicated fashion so as ultimately to form dense masses of pseudo-parenchymatous tissue, about the size of a pin's head, which are at first pure-white throughout, and subsequently become first ochreous and then deep-brown superficially (Plate II, Fig. 6).

The sclerotia, when mature and dry, are very readily detached owing to the rupture of their slender pedicels, and may be found lying loose in large numbers among the dead leaves and on neighbouring surfaces. With the onset of continuous relatively dry and cool weather the extension of the disease is arrested; the dead leaves fall off and a bare patch is left which is anew clothed with leaves in the succeeding spring. But the sclerotia, where they escape the attacks of insects and other destructive agents, do not lose their vitality, but, as may readily be determined experimentally, are capable of lying dormant for many months, and then serving as the source of renewed appearance of the disease when exposed to favourable conditions. I have thus preserved some of them for an entire annual period, and then employed them as the means of establishing patches of blight at an elevation of twenty feet or so above the ground, thereby not merely demonstrating the prolonged vitality of the sclerotia, but also that the fact that the disease normally originates at the level of the soil is simply owing to the fact that the detached sclerotia naturally tend to accumulate there.

The extreme abundance with which sclerotia are produced by this species, and the fact that its parasitism is so feebly specialised that it is capable of attacking very many distinct hosts, renders it most undesirable to employ *Ficus stipulata* as a creeper to screen the sides of any plant-house in which ornamental succulent foliage-plants are cultivated. So long as it was employed thus in the Botanic Garden in Calcutta, the annual blighting of Begonias and other succulents within the houses was enormous, but since it has been replaced by *Ficus repens* and other creepers which are not so subject to attack, the disease has practically disappeared. Sclerotia are produced on the leaves of Begonias and various other plants, but by no means in such abundance as on those of *Ficus stipulata*, and as the blighted leaves of plants within the houses are naturally in greater part removed ere the sclerotia have matured, the numbers of the latter which tend to accumulate as a source of renewed disease are trifling as compared with those which are constantly liable to be present among the remains of the dead leaves of the Ficus at the base of any surface covered by it.

The mycelium grows abundantly on the surface of sections of potato-tubers, producing a densely filled, snowy-white mass of considerable thickness, and its capacity for purely saprophytic existence is demonstrated by the fact that it produces similar although somewhat more limited growths on the surface of media consisting of starch-paste containing sugar and peptones. In either of these cases, however, it fails to produce any sclerotia, so that apparently para-

sitism, although relatively undifferentiated, has been evolved so far that the saprophytism is facultative only.

A large number of the sclerotial blights that occur in India appear to be characterised by a feature which renders them likely to be more extensively mischievous than those which ordinarily occur in Europe. This is that the extension of disease from one part of a host-plant to another, and from one host to a neighbouring one, is effected with great rapidity, in spite of the absence of readily diffusible reproductive bodies such as conidia, owing to the fact that the mycelium is not confined to the interior of the host, but also spreads with great rapidity and luxuriance over the surface, giving off as it does so bundles of invading filaments which penetrate the stomatic orifices and ramify throughout the intercellular spaces and within the cavities of the cells of the tissues. The presence of the blight is therefore rendered readily recognisable even within areas in which the tissues yet retain their normal colour by the presence of strands and webs of white mycelium extending over the surface. For example, in the case of the blight affecting *Ficus stipulata*, the first conspicuous indication of the presence of the disease appears in the form of yellowish or brownish patches of discoloration on the upper surfaces of the leaves ; but if at this time we examine the under surfaces we find that, extending far beyond the limits of the discoloured areas, there are radiant strands of white mycelium spreading over the surface of the epidermis. When the whole of a leaf has been blighted, similar strands extend freely beyond its margins, and where they come into contact with other foliar surfaces, adhere to them and serve as the source of further infection, whilst, where they come in contact with the petiole, they creep along the course of it and of the axis until they reach other leaves. This free superficial extension of mycelium only occurs under conditions of high atmospheric humidity, and consequently we find blights whose extension is mainly determined by it, only presenting themselves conspicuously during the rainy season and producing effects directly proportionate to the degree and duration of excessive atmospheric humidity which prevail in any particular year. Fortunately the foliar tissues alone are attacked by most blights of this type, but very extensive defoliation is yet in many cases effected owing to this capacity for superficial extension of mycelium. Were it not for this, in the absence of readily diffusible reproductive bodies in the form of conidia, only those leaves would be affected which formed the sites of primary infection, but the capacity for free superficial extension serves to replace the presence of conidia and penetration of axial tissues as a means of diffusion so long as atmospheric conditions remain favourable.

The capacity which the mycelium has for invading the interior of the tissues of host-plants varies in degree in various instances. In any case, entrance is mainly effected by means of the stomatic orifices (Plate II, Fig. 7), and in

some cases it appears that it is only by means of the latter or of abnormal interruptions of the continuity of the epidermal surfaces that entrance is capable of being achieved. When a blighted leaf of *Ficus stipulata* clothed with the mycelium of the species of blight naturally affecting it is placed in contact with the under surface of a Begonia leaf, rapid and indefinite superficial extension of mycelium and spreading infection of the new host occurs (Plate II, Figs. 7-9); but, if the Ficus-leaf is applied to the intact upper surface of the leaf, a certain amount of superficial extension of mycelium occurs, but this is very soon arrested on the expenditure of the nutritive supply in the tissues of the primary host, and no infection of the secondary one occurs. This, however, is not the case with another species of sclerotial blight which occurs as a cause of destructive disease in *Evolvulus nummularius*, Linn., and other plants forming common constituents of turf in Calcutta. In this case, whilst infection of Begonia leaves is induced more readily and extends more rapidly when portions of the diseased tissues of the primary host are applied to the lower (Plate II, Fig. 11) than to the upper surfaces, it also constantly occurs eventually in connection with the latter also. The superficial extension of the mycelium is capable of being provided for to a certain extent saprophytically, but it is only where penetration of host-tissues provides nutritive supplies of parasitic origin that it becomes rapid and indefinite. It is thus regulated by two distinct factors, the presence of atmospheric humidity of high degree and of facilities for penetration of host-tissues and acquisition of nutritive supplies from them, and hence it is readily explicable why, as a rule, it should occur so much less conspicuously on the upper than on the under surfaces of leaves, as the latter not only afford greater protection from desiccation, but, as a rule, much greater facilities for penetration than the former do.

Blights of the above nature, which practically limit their attacks to the foliar tissues, are naturally, as a rule, of less economic importance than those which, like the so-called "Bangle-blight" of potatoes, specially attack the tissues of the axis. They give rise to extensive defoliation, but do not necessarily cause the death of the whole or of great parts of their hosts. They may, however, come to be of very considerable importance where they attack plants which are cultivated on account of their foliage, whether for ornamental purposes as is the case with Begonias and other so-called foliage-plants, or for economic purposes as is the case with the tea-shrub, the "Thread-blight" of which would appear, as will be subsequently shown, in all probability to belong to this class of diseases.

e. Sclerotial blight affecting the tubers.—A sample of diseased tubers was received from Poona in February 1894, in which the mischief was dependent on the presence of a mycelium, which, after exhausting the nutritive properties of the host, produced an abundance of ovoid sclerotia, closely resembling those

of the blight of *Ficus stipulata*, but of considerably larger size than these ever are (Plate II, Fig. 1). The affected tubers showed little conspicuous evidence of disease externally, but were more or less softened in texture, and, on being laid open, were found to contain irregular cavities of greater or less extent, the walls of which were coated with thick fleeces of white mycelium. On removing these the subjacent tissue was found to be softened and pulpy for some depth, but appeared not to be penetrated by any fungal elements. In spite of this, however, both the growth of mycelium and the softening of tissue continued to advance rapidly in a moist atmosphere until the tubers were reduced to mere shells containing masses of fungal elements and a moist, ill-odoured pulp. When the nutritive supplies afforded by the latter were exhausted, the sclerotia produced large numbers of sclerotia of ovoid form with average diameters of $75 \times 52\ \mu$, originally pure-white or pale ochreous throughout, but ultimately assuming a deep, rich brown tint externally (Plate II, Fig. 1).

Numerous experiments were tried in regard to the infective power of the mycelium, and it was ascertained that it was capable of giving rise to spreading blight when applied to the leaves of *Ficus stipulata* and various kinds of Begonias, the filaments rapidly extending over the surfaces and at the same time invading the interior by penetrating the stomatic orifices. When applied to the outer surfaces of intact potatoes, a considerable amount of growth occurred in moist atmospheres, but no penetration of the tissues occurred, and the spread of the mycelium was soon arrested without having caused any damage. The effects were, however, very different when the continuity of the rind was interrupted at any point reached by the mycelium, or when the latter was applied direct to raw surfaces. Under such circumstances luxuriant and continued growth occurred, fleeces of white filaments accumulated, the subjacent tissues softened, and, as time went on, all the phenomena present in the case of the original diseased tubers were repeated. In this incapacity for affecting intact tubers and rapid destruction of those presenting raw surfaces, this blight resembles that occurring normally on the leaves of *Ficus stipulata*, and differs from that obtained from *Evolvulus nummularia*, which, although incapable of penetrating the general surface of the rind, does attain access to the interior of the tubers by means of the tissues of the eyes, especially when the latter have undergone a certain amount of development and have come to present stomatic orifices.

The occurrence of extensive destruction of tubers by this form of blight thus implies the presence of some adjuvant agency facilitating access by establishing breaches in the continuity of the epidermal surface. Such solutions of continuity may of course arise in many different ways, but in the instance of this particular sample of tubers there could be no doubt whatever what the really effective agent was, as the tubers were not only affected by the mycelium but also by a species of Acarus; the tissue beneath the fleeces of

fungal elements being in many places swarming with mites such as those which are figured in Plate II, Figs. 2-5. It might have remained an open question whether these were primary or secondary elements in the disease—whether their presence was determined by or determinative of that of the mycelium—had it not been that in a previous sample of blighted tubers obtained from Jullunder in November 1892, they had occurred alone and apart from any fungal elements as a cause of extensive destruction. In this case the tubers presented conspicuous brownish or black scars superficially in sites corresponding with some of the eyes. The texture of the tissues at such points was dry, friable, and permeated by the mycelium of various common moulds superficially, but on section there was no evidence of the invasion of the deeper tissues by any fungal elements. The substance of the tubers was permeated by a complicated system of fissures and cavities bounded by smooth, moist walls, swarming with acari and their ova. Where fresh surfaces of intact tissue were exposed by section, the mites speedily invaded these and proceeded to excavate cavities in them. In cases where the general surface of the epidermis was left intact and the tubers were exposed to a humid atmosphere, they continued to destroy more and more tissue until a mere shell remained persistent, but where the interior of the tubers was exposed by section or rupture of the rind, the tissues rapidly dried up, and with this the progress of the disease was abruptly arrested, the dead portions shrinking and separating from the intact ones and becoming converted into masses of débris full of dead mites and ova.

Here there could be no question that the acari were the primary and efficient cause of the disease. No fungi save purely saprophytic ones were present, and these were confined solely to those portions of the tubers where the tissues had already been completely destroyed and where acari were no longer present, whilst from the distribution of the systems of cavities and the superficial appearances of the tubers there could be no question that the original sites of invasion had been the soft tissues of the eyes. The acari are therefore certainly capable of acting as an efficient and independent cause of the destruction of tubers, and are in addition a source of danger to the latter by rendering them liable to the attacks of destructive fungal elements which, without their aid as factors of rupture of the continuity of the rind, would be unable to attain access to the interior of the tissues. In this case the only fungi which had attained access were pure saprophytes, and therefore of practically no importance in relation to the progress of the disease, but in the specimens from Poona this was no longer the case, because the mycelium was here possessed of parasitic properties and came into play as a secondary destructive agent. The mites alone are capable of effecting the complete destruction of tubers, but the progress of destruction is much more rapid when they are associated with parasitic fungal elements whose access to the tissues of the interior they have facilitated.

Taking the nature of these blights, whether of purely acarine or of mingled acarine and fungal origin, into account, there can be no question that the means to be adopted with a view to limiting their extension and preventing their recurrence must lie in the first place in keeping the tubers as dry as possible, and in the second in carefully removing and burning all those in which the disease has already established itself. The first of these measures will tend to repress the multiplication of both acarine and fungal elements, and the second to secure the destruction of acari, ova and sclerotia, and thus to prevent the reproduction of both the primary and secondary causes which provide for the recurrence of the blight from year to year.

III.—Vegetable blights affecting the Tea-shrub.

a. Bark-blight caused by Cephaleuros virescens, Kunze.—This blight differs from any of the others dealt with in this paper in being dependent on an algal, not a fungal, entophyte, and consequently belongs to a group of diseases of very rare occurrence. Entophytic algae are by no means of uncommon occurrence, but it is only very rarely that they give rise to any serious injury to their hosts. So much so is this the rule that Frank when dealing with the subject affirms that there is only a single exception to it.* In most cases the intrusive elements play the part of pure entophytes and not of true parasites, being dependent on their hosts for mere protection and water-supply, and hence interfering little with their nutrition unless they are present in excessive numbers or are so situated as to interfere with the proper access of air to the system of intercellular spaces. Their injurious effects are, as a rule, of purely mechanical origin and dependent on the pressure which they exert on neighbouring tissue-elements. In many cases, too, the amount of mischief which they thus induce is comparatively trifling, because the intrusive elements are situated only in the substomatic or other larger intercellular spaces, and because of the fact that they are in many cases of unicellular nature, so that even where they are developed within the cells of the host the effect of their presence is very greatly localised. When, however, the algal elements belong to multicellular organisms capable of continuous growth, and are not confined to normal intercellular spaces, they may, even if strictly entophytic in habit, give rise to conspicuous mischief, both because of the abnormal drain on the water-supply of the host which their presence occasions, and by the disruptive effects which they produce on neighbouring tissues. I have already pointed this out in a paper contained in Part III of this periodical, in which the phenomena attending the growth of Cephaleuros on the leaves of *Cinnamomum iners*,

* Die Krankheiten der Pflanzen, s. 635.

Reinwardt, were described,* but the injury which is produced in the host-plant in that case is trifling in comparison to that occurring in connection with the blight induced by the same alga when it attacks the cortical tissues of the shoots of tea-plants.

Specimens of the disease were forwarded to me for examination by Dr. King, of the Royal Botanic Garden, Shibpur, to whom they had been originally sent by the agents of a tea-garden in which it had been the cause of considerable mischief. They consisted of branches bearing the remains of numerous withered leaves on their twigs. The terminal portions of the twigs where the bark was still young and green did not show any signs of disease, but lower down the surface was either covered by dense felts of the fructifying filaments of Cephaleuros, or the bark was entirely wanting and the outer surface of the bast exposed to the air (Plate III, Fig. 1). Vertical and longitudinal sections of portions of shoots in various stages of disease unequivocally demonstrated that the destruction of the bark was owing to the disruptive effects produced by intrusive filaments, sheets and solid masses of the vegetative cells of the alga whose fructification clothed the surface in those places where any bark remained adherent (Plate III, Figs. 2-3). In the earlier stages of the disease the cortex was still of considerable thickness and the algal elements were situated comparatively superficially, spreading out in sheets through the corky strata and breaking up at intervals through it to give origin to erect, fertile filaments on the surface. In more advanced specimens processes could be seen descending through the substance of the host-tissues from such superficial layers, and in their turn spreading out at deeper levels to give rise to new horizontally-disposed extensions which broke up the continuity of the surrounding parts, and in still older cases the thickness of the cortex was greatly reduced (Plate III, Figs. 3-4), and algal elements were visible throughout its entire depth right down to the outer limits of the bast. Taking these appearances into account, there can be no difficulty in accounting for the decortication and ultimate death of the affected shoots. It is evident that the disease originates superficially, and is dependent on penetration of the outer layers of the cortex by processes descending from the under surfaces of the normal discoid expansions of Cephaleuros which are developed on any suitable surface on which the zoospores may happen to come to rest and germinate. Such processes find all the conditions for luxuriant growth in the constant water-supply and protection from direct exposure to the sun's rays which the cortical tissues provide. They grow freely and spreading out horizontally tend to break up the continuity of the tissues and to cause the desquamation of the layers which lie above them, partly by mere increase in bulk, and partly because they give off

* On an Entophytic alga occurring in the leaves of *Limnanthemum indicum*, with notes on a peculiarly parasitic variety of Mycoidea.

numberless emergent fructifying filaments which force their way outwards to the surface (Plate III, Fig. 3). At the same time, they in their turn give off descending processes (Plate III, Fig. 2), like those from which they originated, which force their way downwards into deeper portions of the cortex and give rise to new horizontal expansions. During periods of sunny weather and relatively low atmospheric humidity, the active growth of the algal elements will naturally be retarded, and, at the same time, the superficial layers of them and the disintegrated cortical tissues will tend to dry up and become detached, whilst the deeper strata of the host-tissues, which retain more continuity, persist and afford protection to the algal elements which they contain. When, on the other hand, conditions of excessive humidity once more prevail, active growth will recur and provide for additional disintegration of the host-tissues, and these processes being recurrently carried on, complete destruction of the cortex will ultimately ensue, and the entophytic elements no longer meeting with a suitable nidus, will also disappear, leaving the bast-tissue completely denuded.

The mere abnormal drain upon the water-supply of the host incident on the demands of the intrusive algal elements must necessarily tend to interfere with the nutrition of all distally situated parts even from the outset, and, with the advance towards complete decortication, a purely physical evaporative drain must be established, the ultimate result of which will be a fatal defect in distal water-supply.

The disease is described as tending to occur specially in particularly damp sites, which is just what might have been expected from its origin, seeing that excessive damp must on the one hand favour the vegetative growth, and on the other the reproductive diffusion, of the alga. At the same time the destructive effects which it produces are likely to occur most rapidly and conspicuously in sites which are freely exposed to the sun, and therefore at particular times of year subject to considerable desiccation, as this must both facilitate decortication and also render any abnormal drain on the water-supply of the host more injurious. Under the influence of excessive moisture, on the other hand, the extension of the Entophyte within the host-tissues will occur rapidly, and fructifying filaments will appear in abundance on the surface of the diseased areas and produce innumerable sporangia, the zoosporic contents of which only require the presence of abundant moisture to become fully developed and endowed with active movement securing their diffusion. They will thus be able to spread from their site of development to other previously unaffected areas, and, on germinating, to serve as sources of infection there. Their diffusion, moreover, under the influence of excessive moisture will tend to be effected not only actively, but passively, as multitudes of them may readily be conveyed in any drop of water running along a continuous surface, or falling from a higher to a lower one. There is unequivocal evidence of this in the excessive prevalence of Cephaleuros

which may constantly be found on the leaves of shrubs subject to drip from trees whose leaves are also affected by the alga.

In dealing with a blight of this kind, the great thing must necessarily be to prevent it establishing itself in sites presenting specially favourable conditions for the development of the alga. Cephaleuros occurs abundantly on most diverse hosts in tropical regions, but, as a rule, confines itself almost solely to leaves and produces mere localised mischief in these. The affection of the leaves is, generally speaking, of no practical importance, but it may serve as a source of serious mischief where local conditions are such as to favour the excessive growth and multiplication of the algal elements and their invasion of axial structures in which their presence may give rise to interference with the general water-supply of the host-tissues. The presence of the alga in and on leaves is readily recognisable from the conspicuous orange, lichenoid patches which the superficial discs and tufts of fructifying filaments form on the foliar surfaces, and the diffusion of the disease is a gradual process, and one which can never occur over wide areas with the rapidity with which that of many blights caused by the presence of parasitic fungi is effected. There can, therefore, be little difficulty in successfully contending with it at the outset, and by the careful removal and destruction of all conspicuously affected leaves when it first makes its appearance, and by avoiding planting in sites exposed to the drip from affected trees, any excessive extension of it, even within otherwise specially favourable localities, might be effectually prevented. Where this has been neglected, however, and it has been thus allowed to establish itself thoroughly and to invade large areas of bark, more drastic measures will be necessary in the form of free pruning or even total removal of entire shrubs and careful destruction of all the diseased tissues. The relatively slow growth and the limited means of diffusion of the alga are such that it can only be as the result of the neglect of such simple preventive measures that the disease can ever become of any serious importance in any locality, but, given the neglect, it may be the cause of very considerable mischief.

b. "*Thread-blight.*"—Specimens of this disease have been sent to me by Dr. King, who obtained them from the Darjeeling district, and by Dr. Prain, who found it occurring as a cause of considerable injury to the cultivation of tea in the Andaman Islands. The peculiarity to which it owes its name consists in the presence of conspicuous white cord-like strands of mycelium which run along the surface of the shoots from one leaf to another (Plate III, Fig. 5). They consist of rhizomorphic aggregates of filaments which do not appear to be concerned in the direct acquisition of nutritive material, but merely to serve as means of travel from one nutritive site to another. They are purely superficial, and may readily be rubbed off, leaving the surface of the bark beneath them seemingly quite intact. This, however, is not the case when the mycelium reaches the foliar

surfaces. When the extremity of a cord reaches the base of a petiole, it is either completely diverted outwards along its course, or divides, giving off a branch towards the leaf, whilst the rest of it continues to ascend along the axis. When the mycelium reaches the under surface of a leaf, the cord breaks up and ramifies indefinitely, covering the epidermis with a coating of white filaments, and as this advances the tissues of the lamina throughout become discoloured and die. Where, on the other hand, it comes in contact with the upper surface, only a limited amount of ramification occurs and growth is soon arrested without visible injury to the leaf. It thus behaves in precisely the same fashion as the mycelium of the common sclerotial blight of *Ficus stipulata* does.

The nutritional relations of the mycelium to the upper and lower surfaces of the leaves are quite distinct. The upper surfaces are apparently related to the mycelium just in the same fashion as the bark of the shoots is; they merely serve as a supporting surface over which mycelial filaments deriving their nutrition from other sites may travel, but the under ones are clearly a site for the acquisition of large supplies of fresh nutritive material, as indicated by the indefinite and rapid growth of mycelial elements occurring in connection with it. But the great difference which exists between the upper and under surfaces of leaves generally in their nutritional relations to parasitic or facultatively parasitic fungi lies in the much greater facilities which the latter afford for the penetration of mycelial filaments into the interior of the host-tissues, both from their generally less resistant texture, and from the great excess of stomatic orifices which they present. Taking this into account, together with the destructive effects following the access of the mycelium to the inferior foliar surfaces, and the close parallelism of the phenomena with those present in the case of the blight of *Ficus stipulata*, there is little room to doubt that such penetration does occur. At the same time it must be allowed that none of the specimens which I have had the opportunity of examining have afforded any actual demonstration of the fact. This, however, is not very astonishing, considering the exceptionally dense texture of the leaves and the fact that in all the specimens the tissues had more or less completely dried up ere they were subjected to examination—conditions which are specially calculated to render the detection of intrusive mycelial elements a matter of extreme difficulty. In the case of many uredinous blights, in which the presence of very large numbers of patches of fructification unequivocally implies the existence of abundant and widely diffused mycelium within the substance of the tissues, the demonstration of it is frequently a matter of very great difficulty, even in perfectly fresh specimens, and where the host-tissues are dense and the parasitic elements have been subjected to desiccation, the difficulty is naturally greatly increased.

As has been already pointed out, the phenomena attending the spread of this disease are closely parallel to those occurring in the case of the sclerotial

blights of *Ficus stipulata* and *Evolvulus nummularius*. The principal distinctive feature lies in the definite cord-like arrangement which the mycelium assumes in passing from one nutritive area to another. The distinction, however, is not an absolute one, for, although in the two latter blights the mycelium never forms such definite cords, it does tend to become aggregated in the form of strands in passing from one leaf to another or when spreading out from the edges of an exhausted leaf over neighbouring non-nutritive surfaces such as glass or water. The distinction thus is one of degree and not of kind. In none of the specimens which have yet reached me have there been any traces of true sclerotia either within or on the blighted tissues or in the substance of the mycelial cords, but this may very probably have been owing to the fact that the normal development of the mycelium was arrested by the conditions to which it was subjected after the affected shoots were detached. In certain cases renewed active growth occurred in some of the mycelial cords when subjected to the influence of a moist atmosphere, but in the absence of fresh foliar surfaces as a source of new stores of nutritive material it was soon arrested. The phenomena certainly render it extremely probable that the disease is a sclerotial one, but the question is one which can only be determined in a site in which both parasite and host-plant are at home, but in any such site a little careful observation would be all that would be necessary to decide it.

In the absence of precise information in regard to the true nature of the parasite and the exact form and site of development of the reproductive apparatus, all that can be suggested with a view to the prevention of the disease is that whenever it makes its appearance all infected shoots should, as far as possible, be at once removed and burned. Such treatment will prevent the development of any true sclerotia, should such bodies be normal constituents in the developmental cycle of the parasite, and will at the same time secure the destruction of the dense mycelial cords on the bark the tissue of which does not merely serve as a means of spreading the disease from one leaf to another, but is also capable of retaining its vitality in a dormant condition for some time under conditions fatal to the mycelium generally, and is therefore capable of ensuring the persistence of the disease during periods prohibitive of its active extension.

c. Root-blight dependent on the presence of a destructive fungal mycelium.—Specimens of this disease were sent to me for examination by Dr. King during the winter of the year 1877. As I have already published a note regarding the subject in Part III of this periodical, it is unnecessary here to do more than to give a brief recapitulation of the characteristic phenomena. The morbid changes were purely confined to the lower extremity of the stems and the bases of the larger roots, and presented themselves externally in the form of numerous, conspicuous, irregularly-nodulated swellings, which occurred

so closely over the base of the stem and origins of the larger roots as to be more or less completely confluent, whilst farther out along the course of the roots they occurred in isolated patches (Plate III, Fig. 6). Where they were present, the bark no longer retained its normal smooth texture and grey colour, but was roughened, friable, and deep brown, owing to the mixture of earth, derived from the surrounding soil, with the disintegrated tissues. In certain sites masses of material of rusty-brown colour and spongy texture were visible in fissures of the surface, and, on removing portions of the disintegrating bark, these were seen to form portions of sheets and strands of similarly coloured material traversing the tissues in every direction. Such material was present throughout the entire thickness of the cortical tissues, and specially abundant at the level of the bast, where it was in many places spread out so as to form a continuous stratum over large areas. The wood appeared to be comparatively little affected, but was here and there interrupted by distinct wedge-shaped portions of a greyish tissue, with narrow, sinuous, blackish margins.

On microscopic examination, the rusty-brown substance was found to be composed of dense, felted masses of mycelial filaments of brownish or greenish colour, and in those areas in which the invasion of the disease was progressing, but in which the tissues still retained their continuity, the cortex and bast were found to be everywhere permeated by fine filaments forcing their way between the constituent elements. In the earlier stages of disease, the wood appeared to be entirely unaffected, but, where it was far advanced, the mycelium tended to invade the medullary rays and to give rise to the discoloured radii previously alluded to.

All attempts at cultivating the mycelium with the view of obtaining fructification failed entirely, which is hardly to be wondered at considering that it had evidently been primarily developed parasitically in connection with the living elements of the tissues, and that, by the time the specimens were submitted to examination, the latter were already dead and dried up. A certain amount of growth did occur in some cases, but it was soon arrested and was never attended by the production of any distinct reproductive bodies. The phenomena apparently indicated that the persistent masses of mycelium contained a certain amount of intrinsic nutritive material stored up within them which served to provide for a limited amount of growth, but that, when this had been expended, the latter ceased in the absence of any living host-tissues as a source of further supply. In those cases in which such limited growth occurred, the outer surfaces of the bark became covered by a coating of an orange colour, consisting of short, erect, emergent filaments originating from newly-developed horizontal extensions of mycelium within the substance of the tissues. The development of such emergent filaments in this case is probably an indication of the method in which the extension of the parasite from the roots of one plant to another is

effected. The growth which occurred in the present instance was, no doubt, very limited and only sufficient to give rise to a superficial coating of mycelium on the diseased tissues, but under normal conditions, where the mycelium is in full vigour and the host-tissues still capable of affording abundant nutritive supply, it may well be much more extensive and provide for the development of mycelial strands capable of traversing considerable areas of the soil and so of coming into contact with neighbouring healthy roots.

As the specimens neither contained nor yielded anything save masses of purely mycelial elements, it is impossible to come to any definite conclusion in regard to the precise nature of the parasite, but taking the characters of the disease into account along with the well-ascertained fact of the destructive form of root-blight which prevails in European coniferous forests in connection with the invasion of the tissues by the mycelium of *Agaricus melleus*, Vahl., it appears not improbable that it may be of Hymenomycete origin. Fortunately, however, there can be no doubt in regard to the nature of the measures which ought to be adopted in order to limit the extension of the disease in any area within which it has established itself. All diseased plants ought to be at once removed and burned, and special care should be taken to remove the roots as thoroughly as possible, so that portions of them may not remain in the soil as sources of infection. If possible, moreover, it would be desirable not to replant the infected area for some time, and also to isolate it by means of digging a trench around it sufficiently deep to pass below the lowest level in the soil to which the roots normally penetrate. By such means any extension of mycelium connected with residual fragments of roots remaining in the soil to neighbouring uninfected areas would be effectually prevented, and in the absence of suitable nutritive supply the parasitic elements would, in the course of time, die out within the primarily infected one.

IV.—The Blight of the Opium Poppy (*Papaver somniferum*) caused by *Peronospora arborescens*, de By.

This is a form of disease which is capable of being as destructive to crops of the opium-poppy as that caused by *Phytophthora infestans* is to crops of potatoes; indeed, the mischief which it produces is so great and so rapidly diffused under favourable circumstances that it is probably only because opium cultivation in India is generally conducted within relatively dry localities that it is not absolutely extinguished by it. In regions like the lower Gangetic delta, where atmospheric humidity is normally relatively high and often excessive, it is almost useless to attempt to grow any of the ornamental varieties of the host-

plant, as they are almost invariably entirely destroyed at one or other stage of their development. So much so is this the case, that, as a rule, no garden varieties of *Papaver somniferum* are cultivated in the Botanical Garden at Shibpur, and on the exceptional occasions on which an attempt is made to grow them, even from seed imported direct from Europe and after the cultivation has been intermitted for periods of several successive years, the disease invariably makes its appearance to foil it. A very striking instance of this fact presented itself during the course of the present year. No varieties of opium-poppies had been grown in the garden for eight or ten years previously, but in the winter of 1894 a large bed was planted with seedlings which had been raised from seed freshly imported from Europe in the autumn. As usual they grew vigorously and they had even come into full flower in apparently perfect health, but whenever the temperature began to rise steadily towards the end of February, the blight suddenly made its appearance and spread with such rapidity that within the course of a few days every plant was attacked and killed by it. The relatively high nocturnal temperature and the drenching dews of the deltaic area are specially favourable to the rapid extension of the disease, because they provide conditions favouring the development and evolution of the aërial fructification of the parasite which is the essential cause of it, but, although its destructive effects are not invariably so excessive in dryer regions, it is by no means absent from them and is occasionally a cause of serious mischief there. The very first specimens of the blight which I had an opportunity of examining were sent down from Behar in the year 1874, when it was the cause of very serious damage to the local cultivation of the opium-poppy there.

The presence of the disease is from the outset very readily recognisable from the conspicuous effects which it produces on the affected leaves. They show patches of pale-brown discoloration, which are generally primarily situated towards the tips and margins of the laminæ, but rapidly spread, become confluent, and involve the entire foliar surfaces, which at the same time wilt and soon become dry and brittle. The blight as occurring in Europe is described as occasionally affecting the stems of the plants more conspicuously than the leaves; but in India this phenomenon, if it occur at all, must be very rare, as I have never encountered an instance of it. If the under surfaces of the affected leaves are examined with a lens in the earlier stages of the disease, especially in the early morning and before the dew has evaporated, they are found to be covered by a whitish or very pale ochreous coating of minute, erect, branched filaments bearing terminal sporangia, and, under somewhat higher magnifying powers, it will be seen that they emerge from the interior of the lamina by the stomatic orifices. In the earlier stages of the disease these are the only fungal elements recognisable on the foliar surfaces, but, subsequently, the dead tissues become invaded by saprophytic fungi of many different kinds, the conidial and peritherial

fructifications of which frequently give rise to the formation of variously coloured patches on the originally uniform, pale-brown surface.

The fructifying filaments of the Peronospera are repeatedly dichotomously ramified and terminate in a series of slender, conspicuously curved twigs, so that the entire structure comes to resemble a miniature deer's antler in some degree (Plate IV, Fig. 2). The terminal twigs are short and slender, and each of them gives origin to a sporangium. The sporangia are, when fresh, almost colourless, of rounded-oval figure, with average diameter of $23 \times 20\ \mu$ and contain a mass of finely granular protoplasm within which a nucleoid body may frequently be recognised (Plate IV, Fig. 2). I have not been able to follow out the farther stages of their evolution after they have become detached. Many attempts were made to cultivate them both in water and in neutral salt solution, but in no case did any of them either germinate or give origin to zoospores. This may have been owing to their very rapidly losing vitality after separation, or to an incapacity for farther evolution save when in contact with the host-tissues, but the very rapid extension of the blight under favourable circumstances unequivocally indicates that they are normally capable of undergoing their ultimate development without delay.

On making vertical sections through the thickness of affected portions of the laminæ, the fructifying filaments are found to be continuous with a richly ramified system of septate mycelial filaments filled with granular protoplasm penetrating the entire thickness of the leaf between the superior and inferior epidermis (Plate IV, Fig. 1). The filaments, as a rule, appear to be situated between the cells of the host-tissues, but in some cases give origin to short, simple, rounded, intracellular haustoria.

In some leaves the mycelium produces only sporangial fructification, but in others innumerable oospores are also developed. They make their appearance at a relatively late period and when the nutritive properties of the host-tissues have been more or less expended. I have not yet been able to follow out the details of the earlier stages of their development, but have obtained numerous immature specimens in which the oogonium was still connected with two filaments, one representing the one proper to it, and the other an adherent antheridium, so that there can be no doubt that the fructification is of a truly sexual character (Plate IV, Figs. 4, 5, 7). The mature oogonia are very readily recognisable in the dead tissues owing to the thickness and bright reddish-brown colour of their walls (Plate IV, Fig. 3). They are situated in the interspaces of the open parenchyma beneath the stratum of palisade-cells, and in many places are present in very large numbers. They vary very considerably in size in different instances, but those of average size have diameters of $33\ \mu$. The walls are about $4{\cdot}5\ \mu$ in thickness and surround a central space which is almost entirely occupied by the oospore. The latter has a thin wall

surrounding a peripheral stratum of granular protoplasm including a large central globule of apparently oily matter (Plate IV, Fig. 6). The following figures give the detailed measurements of two mature oogonia and their contents :—

	No. 1.	No. 2.
Diameter of oogonium . . .	43 μ.	33 μ.
Thickness of the wall . . .	4·8 μ.	4·5 μ.
Diameter of the oospore . . .	32 μ.	21 μ.
Diameter of the interior of the oogonium	33·4 μ.	24 μ.

As the oospores have no tendency to undergo any farther evolution immediately after their formation, and as it is only within the past week or two that I have obtained specimens of them, I am unable as yet to follow out their farther evolution.

The fact that they are produced in very large quantities accounts for the regular recurrence of the disease from year to year, in any locality in which the cultivation of the host-plant is annually conducted, and may even possibly account for its regular reappearance in sites, like the Botanic Garden at Shibpur, where long periods of years intervene between the cultivation of successive crops; for it is quite possible that they may be capable of retaining their vitality in a dormant condition for a very long time. One thing is quite certain, and that is that neither any of the cultivated varieties of *Papaver Rhoeas*, nor the thoroughly acclimatised plants of *Argemone mexicana* which every year abound in the neighbourhood of Calcutta are ever appreciably attacked. It is, of course, possible that they may suffer, but to such a slight extent that the event escapes notice, whilst at the same time it yet serves to secure the annual production of a limited number of oospores which serve to secure the persistence of the disease in a smouldering fashion, ready to break out actively whenever the presence of the favourite host-plant is provided; and no doubt, during the long periods during which the cultivation of *Papaver somniferum* are intermitted in the Botanic Garden, numerous crops of it may be grown in the vicinity. At the same time, however, it remains a possibility that the recurrence of the disease on each occasion when the host-plant is grown may have been dependent on strictly local causes and connected with the presence of oospores in the soil persistingly retaining their vitality from the time at which they were developed in connection with the presence of an antecedent crop.

It is not easy to see what measures would be capable of effectually preventing the recurrence and destructive diffusion of the disease in any locality such as the neighbourhood of Calcutta in which the local conditions are such as to provide for the constant and excessive development both of the sporangial fructification and the oospores of the parasite. The oospores are of such small size, and are produced in such abundance that even very minute fragments of the blighted tissues may readily contain very large numbers of them, so that even

if the greatest care is taken to remove and destroy all diseased plants, a certain number of them must almost inevitably escape, and if only a very few do so they will be amply sufficient, in such a favourable locality, to originate devastating disease. In any localities, however, in which such favourable conditions are not present, and in which, in connection with the presence of relative atmospheric aridity, the production of the sporangial fructification is kept within bounds, and therefore the rapid diffusion of the disease is prevented, much might be done to limit the prevalence of it by the careful and early removal and burning of all affected plants, and it is even possible that by means of steady perseverance in such measures it might be totally extinguished.

V.—Root-blight of the Brinjal (*Solanum Melongena*).

Specimens of this disease were sent to me in January 1894 by Mr. Mollison who had obtained them in Gujerat. It was limited to the upper portions of the subterranean part of the axis, being confined to those parts of the roots which contain a medullary area of some magnitude, and thus resemble the stem rather than the deeper portions of the radicular system in which the medulla is practically absent. The external indications of its presence consisted of irregular swelling and roughening of the surface, or of areas within which the outer surface of the primary zone of wood had become exposed owing to the detachment of the cortex, bast and outer stratum of wood in consequence of the friability in the tissues which it ultimately tends to induce. On making transverse sections of the diseased parts it was at once evident that the principal site of disease lay in the secondary zone of wood, but in some places the bast was very conspicuously abortive, and comparative measurements showed it to be throughout abnormally thin in relation to the thickness of the axis. Microscopic examination afforded confirmatory details (Plate V, Fig. 1). It showed that the secondary zone of wood was in some places more or less completely absent, and that everywhere else it was excessively malformed, no longer forming a continuous stratum, but broken up into an aggregate of radiant masses separated from one another by what appeared to be exaggerated medullary rays of non-lignified tissue. The cause of the deformation was demonstrated very clearly, in sections which had been subjected to prolonged treatment with solutions of picro-carmine (Plate V, Figs. 2-5). In transverse sections which had been treated in this way, the abnormal character of the secondary wood was rendered very conspicuous owing to the sharp contrasts in colour which the various portions of it presented, the lignified parts having acquired a bright-yellow tint, whilst the non-lignified ones, like the normal medullary rays of the primary wood-zone, the bast and the medullary tissue, were of various shades of red (Plate V, Fig. 1). Neither the cortex nor the bast showed the presence of any

iungal elements, but a jointed mycelium was present in the substance of the cambium, the wood and the outer portions of the pith. Filaments were present n considerable numbers in the cambium, but the outer zone of the wood was the area within which they specially abounded. In it they were present in great numbers in the wood cells, the large pitted vessels and the proper tissue of the medullary rays, whilst the abnormal unlignified areas between the masses of woody tissue were everywhere crowded with them. Throughout the greater part of the primary zone of wood they were almost entirely absent, the pitted vessels and the wood-cells being entirely free from them and the medullary rays containing traces of their presence only here and there. Just at the inner edge, however, they again made their appearance in some numbers within the medullary rays, and here and there within the spiral vessels and from this area they extended into the immediately adjoining strata of the pith.

Judging from these phenomena, it appears probable that infection did not take place until after the development of the primary zone of wood and that the original site in which the parasitic elements established themselves was the cambium. Their presence there appears to have given rise, as it might have been expected to do, to imperfect development of the secondary strata of both wood and bast, whilst, at the same time, they invaded the tissue of the pre-existent medullary rays to a certain extent and by means of them reached the spirals and the adjoining portion of the pith. The nature of the changes induced in the secondary wood and bast was of unlike character owing to the fact that whilst they underwent excessive development in the tissues of the developing wood they had no tendency to invade the new bast tissue. In consequence of this there had been more defective formation of secondary bast, but extremely abnormal as well as defective formation of the secondary wood, many of the elements which ought to have contributed to its formation retaining an embryonic character and thus giving rise to appearances which to casual observation simulated those of hypertrophy of the medullary rays.

The distribution of the mycelium throughout the tissues of the axis explains why in this case the disease, although in many points closely resembling the so-called "Bangle-blight" of potatoes, should be of a chronic in place of an acute type as the latter is. In the case of the stem of the potato-plant the water-conducting system is a very limited one, consisting of a few isolated bundles of fibro-vascular tissue (Plate I, Fig. 4), and as these are attacked by the mycelium of the parasite the water-supply of all the tissues beyond the invaded area is so seriously interfered with that rapid wilting necessarily occurs. But in the case of the Brinjal, the water-conducting system of the base of the stem is much more highly developed in the form of a continuous zone of wood, so that when, as in the present instance, this is only very partially affected, the water-supply, although interfered with, yet remains sufficient to prevent the

occurrence of total withering of the distal parts. The defect in supply is of sufficient magnitude seriously to interfere with nutrition, but is not so great as to determine immediate wilting and death from disproportion between root-supply and foliar transpiratory loss.

As none of the specimens showed any indications of the development of reproductive bodies of any kind in connection with the mycelium, it was, of course, quite impossible definitely to determine what the precise nature of the parasite was. When, however, the great prevalence of sclerotial blights in India, and the localisation of the disease within the tissues of the host-plant are taken into account, it appears not to be unlikely that the disease is of a sclerotial type. In any case it is clear that the practical measures to be recommended in contending with it are the avoidance of all excessive irrigation and the careful removal and burning of all blighted plants and portions of the dead tissues of such as have already died of the disease.

VI.—Sclerotial Root-blight of Lucern (*Medicago sp.*).

The specimens of this blight, like those of the previous one, were obtained from Mr. Mollison, who sent them from Poona, where (in April and May 1892) the disease was very destructive to Lucern cultivated in the Government farm. It was described as gradually extending from one side of a field to the other causing destruction of fully half of the roots as it did so, and giving rise to a proportionate diminution in the amount of fodder obtainable from the area. The crop was grown on soil "full of manure" and supplied with irrigation water run along the course of furrows between the ridges on which the plants were situated. As in the case of the previous blight, the disease was confined to the bases of the stems and the origins of the larger roots. Where it was present, the surface of the cortex was studded by great numbers of small prominences which in sections were found to be owing to the presence of minute sclerotia of irregularly rounded outline and with diameters of 0·2 m.m. and under (Plate V, Fig. 6). Detailed microscopical examination showed that the tissues were permeated by fungal mycelium, but that this, in place of being specially located within the wood as in the case of "Bangle-blight" and the Brinjal root-blight, was practically confined to the cortex, only here and there invading the bast and then being confined to the most superficial strata in it. The cells in the deeper part of the cortex were in many places crowded with masses of fungal elements and at certain points dense strands of mycelial filaments forced their way out through the corky strata to give origin to the sclerotial bodies previously alluded to (Plate V, Fig. 7), those in an early stage of development being still invested superficially by the remains of the outer layers of cork and the more mature ones showing free upon the surface.

Here again we have an instance of the origin and diffusion of a sclerotial blight under the influence of conditions specially calculated to favour such an occurrence. The soil is stated to have been excessively manured and flooded with irrigation-water, conditions specially adapted to favour the evolution of any sclerotia which may have been originally present in it, and the development of invasive mycelium from the reproductive bodies to which they gave origin. The gradual extension of the disease from one side of the field to the other points to infection spreading from host to host by means of direct extension of mycelium, and, as portions of the diseased roots when exposed to a moist atmosphere became rapidly clothed superficially with emergent white strands of filaments, there can be little doubt that this had actually taken place. In the case of a blight of this character, affecting the superficial tissues and of directly contagious character, the immediate removal and destruction of any diseased plants is, of course, much more important than in the case of the sclerotial root-blights of the Potato and Brinjal which have been previously described and in which the parasitic elements are deeply buried within the substance of the host. This, combined with sparing irrigation and avoidance of any excessive manuring of the soil, would certainly tend to limit the extension of the disease in any area in which it has actually established itself, whilst the tendency to its recurrence at future periods would be obviated by careful burning of all portions of diseased tissues which are likely to harbour sclerotia.

VII.—Stem-blight of the Country-Almond (*Terminalia Catappa*).

This is dependent on the invasion of the tissues of the bark and wood by the mycelium of a species of Trameter. The first evidences of its presence appear in the form of small isolated prominences on the surface, which seem, as a rule, to originate in connection with the bast of embryonic shoots. The onward growth of the shoot is arrested and it assumes the form of a thick turbinate tumour adhering by its broader extremity to the axis. Where the primary site of invasion is on the general surface of the stem, the tumours which gradually arise are irregular in outline and, naturally, less prominent. The disease runs a very chronic course and it is only after it has lasted for a long time that the parasite reveals itself superficially by giving origin to pilei. For a long time the tumours merely go on gradually increasing in size, and, as they do so, becoming confluent with one another. The masses of diseased tissue which are thus formed often attain enormous dimensions and assume very irregular outlines.

In many instances the prominences which they form are half as thick as the stem or bough from which they originate. Ultimately, processes of destructive disintegration set in in the mass, and now the mycelium no longer confines itself to vegetative growth, but gives origin to fructification in the form of crops of deep rusty-brown pilei (Plate VI, Fig. 11) of woody texture and presenting the structural features characteristic of those of the genus Trameter. As the decay of the host-tissues advances, masses of the tumour fall away carrying the earlier crops of pilei with them, and leaving raw surfaces exposed, from which fresh crops originate. In consequence of frequent repetitions of these processes, the bulk of the morbid tissue becomes greatly reduced, but, as the invasion of healthy areas continues simultaneously to progress, any spontaneous cure of the disease does not tend to occur. On the contrary, the general nutrition of the host ultimately comes to be seriously interfered with by the spread of the parasite, and, at the same time, so much weakening is induced by the steady disintegrative loss of tissue, that fractures are readily induced under the influence of any sudden strain such as that caused by gusts of wind.

The appearances presented by the morbid tissues in the earlier stages of the disease, ere disintegrative changes have begun to occur, are illustrated in Fig. 8 of Plate V, which represents a portion of a section through the substance of one of the localised tumours which originate where the original site of invasion is in an embryonic shoot. The particular growth from which the section was obtained was still of small size and its outer surface was quite intact and covered with seemingly normal bark. It will be seen from the figure that the substance of the wood is everywhere permeated by large filaments of a deep-brown, branching, septate mycelium which occur in especial abundance in the large pitted vessels and the tissues of the medullary rays, whilst the wood-cells remain practically exempt. The details of the structure of the mycelium are further illustrated in Fig. 9, which represents portions of individual filaments from various parts of the same section.

This blight is exceedingly common among, and eventually destructive to, trees of *Terminalia Catappa* in the neighbourhood of Calcutta, but there is little doubt that it might be practically abolished were a little attention bestowed on detecting and treating it at an early stage of its development. It so early shows conspicuous indications of its presence, that its invasion can hardly escape notice at a stage long before the parasite has begun to fructify, and when the diseased tissues might readily be completely removed by means of free excision. Such treatment would effectually prevent its further local extension, and also the development of the reproductive elements securing its infective invasion of other hosts, and, considering the ornamental and economic properties of the tree, it is certainly a pity that it should be allowed to suffer as it does.

VIII.—Uredinous blight affecting the leaves of the Teak (*Tectona grandis*).

This disease is excessively prevalent among Teak trees in the neighbourhood of Calcutta, and is probably one reason of the relatively poor growth which they make within the locality. It makes its appearance regularly in the course of the autumn and shortly becomes excessively prevalent, being in fact one of the principal causes which lead to the leaves assuming the very unsightly, tattered appearance which they constantly present during many months of the latter part of their existence. The under-surfaces of the affected leaves become gradually covered by large patches of a brilliant yellow colour, and presently afterwards the tissues of the entire thickness of the lamina in corresponding areas dry up and become brown and so brittle that they readily break away and leave ragged irregular holes in their place. The orange discoloration not infrequently covers the greater part of the entire under-surfaces of the leaves, and, once it has begun to appear, spreads with wonderful rapidity.

On examining the leaves more closely the orange discoloration is seen to be dependent on the presence of a dry, pulverulent material which first makes its appearance in isolated points, but soon becomes diffused and continuous, owing to the confluence of the latter with one another. When examined microscopically, this powder resolves itself into a mass of innumerable orange spores of characteristically uredinous appearance (Plate VI, Fig. 9).

They are broadly oval, or, in many cases, almost spherical in form, giving average diameters of $24 \times 21^{\mu}$, and are provided with a conspicuously and coarsely tuberculate epispore. The presence of germinal pores is hard to recognise, save in the case of spores which have germinated, but in these, under the influence of staining reagents, a varying but always considerable number of them may be detected, distributed irregularly over the surface. They germinate rapidly and freely when ripe, in distilled water, giving origin to germinal tubes, which, within the course of twenty-four hours, have assumed the character of very long, sinuous, occasionally branched filaments, the apices of which are occupied by dense masses of colourless protoplasm and accumulations of orange, oil matter. The mere presence of moisture is thus all that is necessary to induce the contents of the spores to travel over very considerable distances in quest of a suitable nidus for farther development. As a rule, only a single tube emerges from each spore and, as the protoplasm and oil advance along the course of it, the parent spore and the proximal portion of the tube are gradually completely emptied. Mere immersion in water does not obscure the tuberculation of the epispore as it does in the case of many other kinds of uredospores, and

even after germination, the empty spores in many instances retain their tuberculate character very distinctly.

On making vertical sections through the thickness of affected leaves, there is no evidence whatever of any general permeation of the tissues by mycelium (Plate VI, Fig. 9). The double stratum of palisade-cells beneath the epidermis of the upper surface of the lamina is apparently entirely free from fungal elements, and, even in the open tissue beneath, there is no evidence of any continuous system of mycelium. On the contrary, the mycelium appears to occur only in the form of localised patches of dense parenchymatoid tissue composed of closely aggregated cells (Plate VI, Fig. 10), from which the stalks of the uredospores originate.

The normal structure of the leaf of the Teak is somewhat peculiar. Immediately beneath the epidermis of the upper surface there is a stratum of greatly elongated palisade-cells, which is succeeded by another in which the elements are considerably shorter but also arranged in palisade fashion. Beneath this comes a layer of open tissue composed of cells of irregular outline, having large intercellular spaces between them. This tissue is everywhere present save where its continuity is interrupted by lignified cells either belonging to the fibro-vascular bundles or occurring independently of these in the form of supporting pillars passing right through the substance of the lamina from the superior to the inferior epidermis (Plate VI, Fig. 9). It varies, however, greatly in thickness in different places. In many, it is composed of a single row of cells only, but in others, it forms a series of eminences filling into the interior of corresponding projections of the inferior epidermis. In these sites the thickness of open tissue and the area occupied by intercellular spaces is, of course, greater than they are elsewhere, and it is to them that the mycelium of the parasite apparently is paractically confined (Plate VI, Fig. 9). Here it forms isolated, parenchymatoid beds of closely appressed cells in the deeper parts of the open tissue and from these cellular masses the pedicels of the urebospores originate, filling up the interior of the prominences as they increase in size and numbers and ultimately rupturing the continuity of the epidermis to project free upon the surface of the lamina.

In spite of this essentially localised distribution of the mycelium, the extension of the disease and of the coincident destruction of the tissues of the host is very rapid, owing to the readiness and rapidity with which the uredospores germinate and the great length which the resultant germinal tubes are capable of attaining in their search for a suitable site for further development. All that is necessary is the presence of a certain amount of moisture—that which is nightly provided in the lower Gangetic delta by drenching dew being amply sufficient—in order to secure the immediate germination of the ripe spores, whilst, as the energy of the mycelium which arises subsequent to the access of

the germinal tubes to the interior of the host, is apparently immediately devoted to the local production of beds of fructiferous tissue, no time is lost in the development of new crops of spores.

All attempts to discover any other form of fructification save this uredinous one have hitherto entirely failed. In spite of the constancy and excessive abundance with which the uredospores are produced, no traces of any teleutosporic fructification have appeared on any of the numerous specimens of blighted leaves which have been examined, and, in spite of repeated and careful search, no satisfactory evidence of the presence of any intermediate host producing the missing forms of fructification has been obtained. That such an intermediate host does exist there can, however, be little doubt, as in the entire absence of any teleutosporic fructification on the leaves of the Teak, there would appear to be no other theory by which to account for the constant annual recurrence of the disease. It is not as though the successive crops of leaves normally overlapped one another, as they do in the case of certain other trees, such as *Bassia longifolia*, which are annually affected by uredinous blights devoid of teleutosporic fructification, for a considerable period always elapses between the fall of one set of leaves and the appearance of the next one. Moreover, during a prolonged period in the earlier part of the existence of each successive crop of leaves, the latter show no traces whatever of being affected, and, when they do begin to do so, the fructification is from the outset uredinous, which may be taken to indicate that uredospores are the primary cause of infection.

I have, unfortunately, no information regarding the extent to which the disease prevails in other localities than the neighbourhood of Calcutta, but it appears to be not improbable that in drier regions its recurrence and diffusion may be very considerably checked by the absence of conditions favouring the rapid germination of the successive crops of uredospores. In the lower Gangetic delta, however, where atmospheric humidity is constantly relatively high and where heavy falls of dew normally occur even during the driest periods of the year, the amount of destruction of leaf-tissue which it annually occasions must be enormous, and must certainly be well calculated to interfere seriously with the nutrition of the host-trees. The mycelium, no doubt, appears to be very localised in its distribution throughout the foliar tissues, but the number of individual points of infection is enormous. Each individual patch of mycelium may only be capable of acting as a very limited drain on the nutrition of the host, but the sum of drain determined by the coincident action of innumerable patches must be very great indeed. Moreover, the destructive effects on the leaf-tissues are not determined merely by the amount of direct abnormal drain on nutritive supply by the parasitic elements, for the latter also mechanically cause such extensive destruction of epidermis as must inevitably lead to the death of neighbouring and deeper tissues in consequence of the incident

abnormal loss of water from the laminar surfaces. The excessive prevalence of the blight may thus well be one factor in determining the very imperfect growth of the Teak-tree in Lower Bengal.

IX.—Destructive fungal blights affecting seedling Conifers.

Specimens of two distinct blights of this nature were sent to me by Mr. J. S. Gamble and are illustrated in the first seven figures in Plate VI. The first occurred in seedlings of *Pinus longifolia*, and caused considerable loss among them, "the needles becoming blackened and brittle and the entire shoot ultimately dying." On microscopic examination, the entire thickness of the open tissue beneath the epidermis was found to be permeated by a brown, closely septate mycelium (Plate VI, Fig. 1). At certain points this gave origin to dense masses of similar filaments from the free surfaces of which numberless conidial cells were given off (Plate VI, Figs. 2-3). They pressed outwards against the under side of the epidermis, and, ultimately rupturing its continuity, appeared free on the surface of the needles. In addition to this, small groups of considerably larger and very dark brown conidia occupied the cavities of the stomatic vestibules in sites where the mycelium abounded in the corresponding substomatic spaces (Plate VI, Figs. 4-5). The general blackening of the surfaces of the needles which formed such a prominent feature of the disease appeared to be mainly owing to the accumulation and germination of both the forms of conidia which are thus set free.

The second blight occurred in forest-sown seedlings of the Deodar (*Cedrus Libani, var. Deodara*), in the neighbourhood of Chakrata. In this case, the disease did not occasion any conspicuous blackening of the needles like that present in the previous blight, the affected tissues merely drying up and acquiring a bright brown colour and brittle texture. There were no external evidences of the presence of fungal elements of any kind, but vertical sections through the thickness of the needles revealed the presence of an abundance of large, pale-brown, septate mycelial filaments ramifying through the substance of the open, chlorophyll-containing tissue between the hypodermis and the colourless parenchymatous sheath of the vascular bundle, around which they, in many cases, tended to form a more or less continuous stratum (Plate VI, Figs. 6-7). No signs of fructification of any kind were present in any of the specimens.

Calcutta, March 22nd, 1895.